Int.J.Curr.Res.Aca.Rev; **Special Issue-2 (January-2015)**: *102-111*

International Journal of Current Research and Academic Review

EXCELLENT PUBLISHERS

ISSN: 2347-3215 Special Issue-2 (January-2015) pp. 102-111

www.ijcrar.com

Impact of airport activities on local scale air quality

L.A.Jimoda[1], J.A.Sonibare[2], B.S.Fakinle[2], J.A.Adeniran[1]*, F.A.Akeredolu[2] and O.Seriki[3]

[1]Environmental Engineering Research Laboratory,Department of Chemical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[2]Environmental Engineering Research Laboratory, Department of Chemical Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria
[3]Global Environmental Technology Limited, Lagos, Nigeria
***Corresponding author email id:** adeniranadetayo@yahoo.com*

KEYWORDS

Emission sources, ground level concentration, Agro airport, receptor location

A B S T R A C T

This work studies the potential impacts on air quality of an Agro Cargo Airport proposed for Southwestern Nigeria. An emission inventory was carried out for emissions of sulphur dioxide (SO_2), oxides of nitrogen (NO_X), particulate matter (PM), carbon monoxide (CO) and hydrocarbon (HC) taking into account emission sources' characteristics. The resultant concentration on the host area of influence was determined using an ISC-AERMOD View Version 4.8. Combination of all the changes with the present status of air quality in the study area signifies the need for conscientious effort on air quality control in the proposed airport for environmental and health benefits during its operation.

Introduction

Air transportation is a unique option that can be used to achieve connectivity between widely distributed locations (Halpern and Bråthen, 2011; Donehue and Baker, 2012). However, emissions from aircrafts and supporting facilities in the airport have adverse impact on air quality and public health (Fang *et al.*, 2007; Stettler *et al.*, 2011; Yim *et al.*, 2013). According to Kurniawan and Khardi (Kurniawan and Khardi, 2011), environmental impacts of atmospheric emissions from aircraft can either be aircraft pollutant emissions occurring during the landing and take-off (LTO) phase (local pollutant emissions) or the non-LTO phase (global/regional pollutant emissions). Emissions from airports are either in particulate or gaseous form. These include CO_2, NO_x, CO, SO_x and particulates (FAA 2005; Gauss *et al.*, 2005). They are emitted from handling, infrastructure, stationary and traffic related sources (NRDC, 1996). Aviation sources include emission from aircraft, auxiliary power units and ground support equipments. To estimate the impact and concentrations of these pollutants in ambient air and the receptor environments, dispersion modelling tools are often employed.

Several studies have employed dispersion modelling tools to investigate and characterize patterns of emission and dispersion of pollutants around the airports environments (Unal *et al.*, 2005; Steib *et al.*, 2008; Lofstrom *et al.*, 2011) Unal *et al.* (2005) used the Models – 3 System to characterize patterns of $PM_{2.5}$ and ozone due to emissions from activities in Atlanta's International Airport. Steib *et al.* (2008) used EDMS (Emissions and Dispersion Modeling System) model for airport air quality analysis at Ferihegy airport. Lofstrom *et al.* (2011) measured and modeled the hourly air pollution level at different locations at the Danish airport and Clench–Aas *et al.* (1999) conducted an integrated exposure monitoring system based on the expansion of existing air quality monitoring system using dispersion modeling. This study looks at the evaluation of the environmental impacts of the proposed agro airport on the ambient air of the local receptor environments. The ground level concentration of pollutants from the proposed agro airport was predicted using ISC- AERMOD.

Methodology

Emission sources

Emission inventory and dispersion modeling are often used to estimate the ground level concentration of the identified pollutants at specific location of interest with a view to determining the number of people exposed to air pollution so as to develop a land use planning to minimize the exposure to the risk. The air pollutants considered in this study are carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2), particulate matter less than 10 microns (PM_{10}), and hydrocarbons (HC). This airport is proposed for Iperu between the Sagamu interchange along the Lagos-Ibadan expressway and the Sagamu-Benin expressway in Ikene Local Government Area of Ogun State, in the south-western part of Nigeria, Latitude 6° 55' 0 N and Longitude 3° 40' 0 E (Figure 1). The ground level concentrations of criteria air pollutants from the proposed project's facilities were computed and compared with the standards (Table 1) derived from the World Bank Environmental Guidelines and the Nigerian Ambient Air Quality Standards issued by the Federal Ministry of Environment (FMENV).

The identified sources in the study include the aircraft movements, refueling, aircraft maintenance, facility access, carp parks and traffic which can be categorized into air side emissions and land side emissions.

Using the ICAO Grouping technique (ICAO, 2007) the emission sources in this study have been grouped into four categories including: aircraft emissions, infrastructure or stationary related sources and vehicle traffic sources. The aircraft emission sources are the aircraft main engines within specified perimeter from start-up to shutdown and the auxiliary power units (APU) located on-board aircraft providing electricity and preconditioned air during ground times and bleed air for main engine start. Emissions from aircraft handling sources are those from the ground support equipment (GSE) necessary to handle the aircraft during the turnaround at the stand which may include ground power units, air climate units, aircraft tugs, conveyer belts, passenger stairs, fork lifts, tractors, and cargo loaders. An MD11 size freighter operating four times a week providing a yearly capacity of 38,000 tones both ways is assumed for the study. By 2015 it is envisaged that this will have increased to daily flights and 80,000 tones capacity a year as proposed for the airport. At this stage, operations could potentially attract a second operator. Potentially this operator could establish a 5 weekly B747-400F, increasing the annual capacity up to around 120,000 tones by 2025 (OACA, 2009). Passenger flights are anticipated in addition to the cargo freights at the airport serving the main internal markets proposed on a non-stop basis. To achieve this, the aircraft types to be operated would be the B737-700 or A319 type with around 150 seats. It was assumed that almost all passenger flights will be domestic over the forecasting period.

However, it is more likely that the B737-700 or A319 would be used at least initially. The number of daily departures is forecast to increase from 7 in 2010 to 20 in 2025. These are likely to be spread over the day, but with 4-5 aircraft departing at peak hour in 2010, around 6–7 in 2015 and 8–9 in 2025. In terms of total aircraft movements (cargo and passenger), initial airport operations will comprise 11 movements per week in 2010 which will have tripled to 32 movements per week (Table 2). To obtain emissions from these sources, complete LTO cycle for each of the trips in and out of the airport was considered. This was combined with the emission factors obtained from the ICAO (USEPA, 1995) information.

The infrastructure or stationary related source categories will include emissions from power/heat generating plant, emergency power generator, aircraft maintenance, airport maintenance, fuel, construction activities, and fire training while vehicle traffic sources are those from bikes, cars, vans, trucks, busses drive-ups, on- or off-site parking lots including engine turn-off, and start-up at the car park located within the airport. In this study, the airside location will be the runways and the taxiways while the landside locations will be the truck container park, the car park, and the electric power generator support facilities locations.

The air pollutants modelled for the ground level concentrations include: PM_{10}, carbon monoxide (CO), oxides of nitrogen (NO_X), sulphur dioxide (SO_2) and hydrocarbons (HCs). The emission rates and exhaust vent stack parameters (height, diameter, exhaust temperature, and exit velocity) used as model input parameters were obtained from manufacturers of facilities.

An APU assumed for this study is a small gas-turbine engine coupled to an electrical generator and is used to provide electrical and pneumatic power to aircraft systems when required. It is normally mounted in the tail cone of the aircraft, behind the rear pressure bulkhead, and runs on kerosene fed from the main fuel tanks. Not all aircraft are fitted with APU, and though their use on transport category jet aircraft is now almost universal, some turboprops and business jets do not have an APU fitted. This study however assumed that all the aircrafts that will operate in the proposed airport are fitted with APU.

Emissions from auxiliary power units (APUs) were calculated for the aircraft exhaust emissions as provided in (EPA, 2007). APU

emissions were calculated for one complete LTO cycle of each aircraft type using the emission factors and fuel flow for the aircraft's specific APU model and the amount of APU usage during the course of the full aircraft LTO as calculation inputs assuming that each aircraft type has one APU. Using the aircraft anticipated as summarized in Table 2, the anticipated APU were taken from EPA (USEPA, 1995) and summarized in Table 3.

Emissions from aircraft handling were taken to be from sources including ground support equipment (GSE), airside vehicle (engine exhaust), and aircraft refueling. Using the ICAO (2007) typical emission factors for aircraft handling, the anticipated emissions were calculated.

Infrastructures and stationary source emissions in the airport in this study included power/heating generating plants, incineration and food preparation activities, and construction activities. However due to the peculiarity of the power supply status from the national grid in Nigeria, the major source of stationary emissions are the electric power plants. Estimates of the airport maximum power demands are based on the electrical load density criteria and built up areas of all buildings and facilities as given in (OSACA, 2007) in the proposed airport. The total anticipated energy demand of 7068 kVA (Table 4) will be from electric power generators as alternative to the national grid. As proposed in the project, four units (Power Generators 1 – 4) of 1500 kVA electric power generators and five units (Power Generators 5 – 9) of 250 kVA of electric power generators are assumed as the possible sources.

The electric power generators emission sources used with the emission rates and stack parameters for all sources are summarized in Table 5 as obtained from manufacturer information manual. Table 6 summarized the anticipated emissions from these identified sources that served as key inputs into the modelling exercise.

The other emission sources in the proposed airport identified in this study are vehicles from the car parks. About 720 vehicles were anticipated as the worst scenario. Of these 720 vehicles, 70 % were taken to be cars while the remaining 30 % were assumed to be bus.

At the same time, about 1000 motorcycles are equally being anticipated daily. To predict the emissions from these sources, emission factors as reported by NAEI (2009) were used with assumptions that: the cars, buses and motorcycles run on gasoline. Emission calculations were based on: vehicles driving around the park to secure parking space, vehicles starting at the car park to leave and vehicles queuing at the proposed airport gat for exit. The ISC-AERMOD View was used in this study.

Result and Discussion

The predicted maximum concentrations of air pollutants anticipated from the electric power generators in the proposed airport as obtained from the ISC-AERMOD View model runs are summarized in Table 7. The maximum predicted ground level concentration of all the parameters considered is 20.3 $\mu g/m^3$, the 24-hour highest concentration predicted for NO_X in the south end of the airstrip fenceline while the minimum predicted concentration is 0.3 $\mu g/m^3$, the 24-hour highest concentration of NMHC also obtained in the south end of the airstrip fenceline.

The 1-hour, 8-hour and 24-hour highest concentrations of CO within the vicinity of the proposed airport as obtained from the ISC-AERMOD View runs during the study. While the predicted 1-hour CO concentrations range between 0.1 and 10.0 $\mu g/m^3$, the predicted 8-hour and 24-hour concentrations ranges are 0.1 – 5.7 $\mu g/m^3$ and 0.1 – 2.8 $\mu g/m^3$ respectively. For the 1-hour averaging period concentrations, the minimum concentration obtained within the perimeter fenceline of the airstrip is 6.8 $\mu g/m^3$, obtained at about 1.06 km in the NE flank while for the 8-hour averaging period, the minimum concentration of CO within the perimeter fenceline is 2.8 $\mu g/m^3$ predicted for the 0.94 km NW flank and the 24-hour minimum predicted concentration of CO is 2.0 $\mu g/m^3$ obtained at about 0.95 km NW flank of the airstrip.

The 24-hour concentrations of NO_X as predicted from the electric power plants in the proposed airport which range between 0.1 and 20.3 $\mu g/m^3$. About 13.9 $\mu g/m^3$ obtained at 1.0 km NW flank of the airstrip is the predicted highest concentration within the perimeter fenceline of the proposed airport while the nearest community with the highest 24-hour averaging period concentration is predicted to be Ilishan which has about 19.7 $\mu g/m^3$. The predicted 24-hour averaging period concentrations of PM_{10} as obtained from the study range between 0.02 and 2.85 $\mu g/m^3$ obtained respectively at distances 1.9 km in the South West direction and 0.75 km in the South Flank from the proposed airport with 2.0 $\mu g/m^3$ obtained at 0.97 km Northwest being the minimum concentration within its perimeter fenceline and 2.7 $\mu g/m^3$ as the maximum in the nearest community.

Table.1 Comparison of ground level concentrations of air pollutants with the standards – FMENV and World Bank Environmental Guidelines

S/No	Contaminant	Averaging Period	Maximum Concentration ($\mu g/m^3$)	
			FMENV[a]	World Bank[b]
1.	CO	1 – Hr		30,000
		8 – Hr	22,800	10,000
		24 – Hr	11,400	
2.	NO_X	24 – Hr	75 – 113	150
3	SO_2	1 – Hr	260	
		24 – Hr	26	
4.	PM_{10}	24 – Hr		80
5.	NMHC	24 – Hr	160	-

[a]Source: FEPA (1991); [b]Source: World Bank (1998)

Table.2 Summary of aircraft emission sources

Period	Aircraft	
	Freighters/Week	Passengers/Week
2010	4 MD11	7 A319
2015	7 MD11 and 5 B747-400F	7 A319 and 7 B737-700
2025	7 MD11 and 5 B747-400F	10 A319, 10 B737-700

Table.3 Summary of anticipated APU emission sources

Period	Auxiliary Power Unit	
	Freighters/Week	Passengers/Week
2010	4 TSCP 700	7 GTCP 331 Series
2015	7 TSCP 700 each and 5 PW 901A	7 GTCP 331 Series and 7 GTCP 85 Series
2025	7 TSCP 700 and 5 PW 901A	10 GTCP 331 Series, 10 GTCP 85 Series

Table.4 Projected electric demand in the proposed airport buildings and facilities

Zone	Buildings	Load (kVA)	
		Connected	Demand
Public Buildings	Terminal Building	540	432
	General Aviation Building	300	240
	Cargo	800	640
Technical Buildings	Technical Block and Control Tower	100	80
	Main Fire Station	81	65
	Central utility complex	65	52
	Electrical Substation	33	26
Administration Buildings	Airport administration building	96	76.8
Fuel farm buildings		133	106.2
Catering		60	48
Warehouse maintenance for motors and civil works		60	48
Aircraft maintenance hangars		320	256
GSE repair shop and airport maintenance building		60	48
Fuel farm equipment		1500	1200
Airfield lighting equipment		1500	1500
Central utility complex cooling load		2250	2250
Total kVA		7898	7068

Table.6 Computed air pollutants from the Identified electric power generator

Source	TSP	CO	HC	NO_X	SO_2
Power Gen. 1 (g/s)	0.0031	0.0754	0.0086	0.4976	0.0407
Power Gen. 2 (g/s)	0.0031	0.0754	0.0086	0.4976	0.0407
Power Gen. 3 (g/s)	0.0031	0.0754	0.0086	0.4976	0.0407
Power Gen. 4 (g/s)	0.0031	0.0754	0.0086	0.4976	0.0407
Power Gen. 5 (g/s)[3]	0.0005	0.0043	0.0008	0.0591	0.0068
Power Gen. 6 (g/s)[3]	0.0005	0.0043	0.0008	0.0591	0.0068
Power Gen. 7 (g/s)[3]	0.0005	0.0043	0.0008	0.0591	0.0068
Power Gen. 8 (g/s)[3]	0.0005	0.0043	0.0008	0.0591	0.0068
Power Gen. 9 (g/s)[3]	0.0005	0.0043	0.0008	0.0591	0.0068

Sources in the Proposed Ogun State Agro Cargo Airport1
1Calculated from given emissions from 1500 KVA
2Calculated from AP-42 given emission factor for SO2 (Table 3.4.2)
3Calculated from given emissions from 250 KVA

Table.7 Predicted maximum concentrations from the power generators

Air Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Receptor Location		
			Coordinates		Nearest Community
			X, m	Y, m	
CO	1-Hr	10.0	9258.06	3967.74	South of Airstrip Fenceline
	8-Hr	5.7	10580.64	3967.74	Ilishan
	24-Hr	2.8	9258.06	3967.74	South of Airstrip Fenceline
NO_X	24-Hr	20.3	9258.06	3967.74	
PM_{10}	24-Hr	2.9	9258.06	3967.74	
SO_2	1-Hr	6.3	9258.06	3967.74	
	24-Hr	1.8	9258.06	3967.74	
NMHC	24-Hr	0.3	9258.06	3967.74	

The two averaging periods with standards in Nigerian ambient air for SO_2 are 1-hour and 24-hour. When these are considered in the study, the predicted highest concentrations in the same order are of the range 0.01 – 6.26 $\mu g/m^3$ and 0.01 – 1.76 $\mu g/m^3$ as shown in Figure 5.

While the minimum and maximum of the 1-hour averaging period concentrations are predicted to be at 4.5 km and 0.6 km respectively, they are respectively at 1.9 km and 0.7 km in the 24-hour averaging period concentrations. In the two averaging periods, the minimum concentrations are at the southwest direction of the proposed airport while the maximum are s at south direction.

The operations of aircrafts in, out and around the proposed airport are bound to generate some levels of air pollutants which may have negative impacts on the ambient air quality of the environment. In the first phase of operation between the year 2010 and 2014, the expected HC expected from these activities is 0.0222 g/s but in both the second and third phases of aircraft operations in the airport, HC emissions from aircraft engines are expected to be about 0.0634 g/s and 0.0698 g/s. Between the first and third phases, emissions of NO_X and CO are predicted to be 0.3361 – 1.0591 g/s and 0.2093 – 0.6944 g/s while the expected SO_2 from aircraft engines in the first phase to the third phases range between 0.0222 and 0.0793 g/s in the ambient environment.

In all the neighboring communities of the proposed airport investigated the minimum change in ambient air quality parameter is predicted to be about 0.01 % of the FMENV limit of PM_{10} expected from the Lagos-Ibadan expressway while the maximum change in ambient air quality status is predicted to be 17.40 – 26.21 % of the FMENV limit for NO_X obtained around the south eastern direction of the airport. In most of these communities, the electric power generators proposed for the project may have no significant impacts on their ambient air quality. The possible air quality impact of the proposed airport on some neighbouring communities is summarized in Table 8.

Table.8 Possible air quality impact of the proposed airport on some neighbouring communities

Communities	CO		NO_X		PM_{10}		SO_2		HC	
	Predicted (μg/m^3)	% FMENV Limit	Predicted (μg/m^3)	% FMENV Limit	Predicted (μg/m^3)	% FMENV Limit	Predicted (μg/m^3)	% FMENV Limit	Predicted (μg/m^3)	% FMENV Limit
Ilara	0.55	0.00	3.90	3.45 – 5.20	0.55	0.69	0.34	1.31	0.09	0.06
Irolu	0.39	0.00	2.81	2.49 – 3.75	0.39	0.49	0.25	0.96	0.05	0.03
Ilisan	2.71	0.02	19.66	17.40–26.21	2.71	3.39	1.72	6.62	0.33	0.21
Iperu	1.07	0.01	7.66	6.78 – 10.21	1.07	1.34	0.66	2.54	0.13	0.08
Ogere	0.51	0.00	3.68	3.26 – 4.91	0.51	0.64	0.32	1.23	0.06	0.04
Ode Remo	1.30	0.01	9.38	8.30 – 12.51	0.84	1.05	0.53	2.04	0.16	0.10
Akaka	0.84	0.01	6.02	5.33 – 8.03	0.84	1.05	0.52	2.00	0.10	0.06
Ijebu-Ijesha	0.42	0.00	3.01	2.66 – 4.01	0.42	0.53	0.26	1.00	0.05	0.03
Ikene	0.36	0.00	2.56	2.27 – 3.41	0.36	0.45	0.22	0.85	0.04	0.03
Shagamu	0.27	0.00	2.02	1.79 – 2.69	0.27	0.34	0.18	0.69	0.03	0.02
Odogbolu	0.47	0.00	3.37	2.98 – 4.49	0.47	0.59	0.29	1.12	0.06	0.04
Araromi	0.00	0.00	0.20	0.18 – 0.27	0.03	0.04	0.02	0.08	0.00	0.00
Makun	0.18	0.00	1.26	1.12 – 1.68	0.18	0.23	0.11	0.42	0.02	0.01
Idofin Isale/Idofin Oke	0.26	0.00	1.80	1.59 – 2.40	0.26	0.33	0.16	0.62	0.03	0.02
Logbara	0.03	0.00	0.19	0.17 – 0.25	0.03	0.04	0.02	0.08	0.00	0.00
Lagos-Ibadan Highway	0.01	0.00	2.25	1.99 – 3.00	0.01	0.01	0.20	0.77	0.04	0.03
Ore-Shagamu Highway	0.79	0.01	5.58	4.94 – 7.44	0.79	0.99	0.48	1.85	0.09	0.06

Conclusion

The major sources of air pollutants identified from the proposed agro cargo airport and its facilities in this modeling exercise are aircraft operations and the handling equipment, stationary electric power generators, and vehicular activities at the car park. Within the limits of the several assumptions used in the ISC-AERMOD View modeling tool used, the predicted 1-hour CO concentrations range between 0.1 and 10.0 μg/m^3 while the 8-hour and 24-hour concentrations ranges are 0.1 –5.6 μg/m^3 and 0.1 – 2.8 μg/m^3 respectively.

The predicted 24-hour averaging period highest NO_X concentrations range between 0.1 and 20.3 μg/m^3, PM_{10} range between 0.02 and 2.85 μg/m^3 and NMHC range between 0.01 and 0.34 μg/m^3. For SO_2, the predicted 1-hour and 24-hour averaging periods highest concentrations are 0.01 – 6.26 μg/m^3 and 0.01 – 1.76 μg/m^3 respectively. In all these parameters, the highest concentrations are generally within the perimeter fenceline of the proposed airport especially to the south flank while Ilishan is the nearest community with possibility of receiving highest emission concentrations from the airport activities.

All these changes within the airport and its host environment combined with the present status of air quality in the study area signify the need for conscientious effort on air quality control in the proposed airport for environmental and health benefits during its operation. Emissions from the proposed airport can be reduced by ensuring and enforcing strict compliance with the ICAO standards. Payment of environmental cost (transport externality) may be introduced using data on aircraft and auxilliary facilities emission used by the different operators.

References

Clench–Aas, J., Bartimova, A., Bohler, T., Gronskei, K. E., Sivertsen, B., Larssen, S. 1999; Air pollution exposure monitoring and estimating: Part 1. Integrated air quality monitoring system. *J. Environ. Monitor.*, 1: 313–319.

Donehue, P., Baker, D. 2012. Remote, rural, and regional airports in Australia. *Transport Policy*, 24: 232–239.

FAA, 2005. Aviation & emissions a primer. Office Environment and Energy.

Fang, G.C., Wu, Y.S., Lee, W.J., Chou, T.Y., Lin, I.C. 2007. Study of ambient air particulates pollutants near taichung airport sampling site in Central Taiwan. *J. Hazard. Mater.*, 144: 492–498.

FEPA, 1991. Guidelines to standards for environmental pollution control in Nigeria. Federal Environmental Protection Agency FEPA, Lagos.

Gauss, M., Isaksen, I., Lee, D., Sovde, O. 2005. Impact of aircraft NO_x emissions on the atmosphere-tradeoffs to reduce the impact. *Atmos. Chem. Phys. Discuss.*, 5: 12255–12311.

Halpern, N., Bråthen, S. 2011. Impact of airports on regional accessibility and social development. *J. Transport Geogr.*, 19, 1145–1154.

ICAO, 2007. Airport air quality guidance manual, International Civil Aviation Organization, Document 9889, Preliminary Edition, 15 April 2007.

Kurniawan, J.S., Khardi, S. 2011. Comparison of methodologies estimating emissions of aircraft pollutants, environmental impact assessment around airports. *Environ. Impact Assess. Rev.*, 31, 240–252.

Lofstrom, P., Ketzel, M., Winther, M., Kousgaard, V., Christensen, J., Geels, G., Massling, A., Nojgaard, J. K., Ellerman, T. 2011. Air Pollution Level at Capenhagen Airport Estimated by Measurements and Nested Regional Euclerian Local Gaussian Plume and CFD Models. Proceedings of the 14th International Conference. Pp. 569–573.

NRDC, 1996. Flying off course organized by National Resources Defense Council.

OACA, 2009. Aviation and the environment: Strategic framework needed to address challenges posed by aircraft emissions. U.S. General Accounting Office, GAO-03-252.

Steib, R., Ferenczi, Z. and Labancz, K. 2008. Airport Ferihegy - Hungary Air Quality Analysis using the EDMS Modeling System, proceedings of the 11th International Conference on Harmonization within Atmospheric Dispersion Modeling for Regulatory Purposes. Pp. 407 – 411.

Stettler, M.E.J., Eastham, S., Barett, S.R.H 2011. Air quality and public health impacts of UK airports. Part I: Emissions. *Atmos. Environ.* 45: 5415 – 5424.

Unal, A., Hu. Y.T., Chang, M.E., Odman, M.T., Russell, A.G. 2005 Airport related emissions and impacts on air quality: application to the atlanta international airport. *Atmos. Environ.*, 39: 5787–5798.

USEPA, 1995. Estimation and Evaluation of cancer risks attributed to air pollution in Southwest Chicago. U.S. Environmental Protection Agency. Region 5, Chicago, Illinois.

World Bank, 1998. Pollution prevention and abatement handbook WORLD BANK GROUP, Washington, DC.

Yim, S.H.L., Stettler, M.E.J., Barett, S.R.H. 2013. Air quality and public health impacts of UK Airports. Part II: impacts and policy assessment. *Atmos. Environ.,* 67: 184–192.